Development of Level 1 probabilistic safety assessment incorporating portable equipment

Ji Suk KIM [a], Man Cheol Kim[a*]
[a]*Department of Energy Engineering, Chung-Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul, Korea*
[*]*Corresponding author: charleskim@cau.ac.kr*

1. Introduction

Since the Fukushima accident, nuclear industry has developed various strategies such as diverse and flexible coping strategies (FLEX) in the United States, and multi-barrier accident coping strategy (MACST) in Korea [1,2]. These strategies are in preparation for the beyond design basis external events (BDBEE) and several portable equipment has been prepared [3]. In this paper, as a part of researches from the multi-unit risk research group (MURRG) to develop multi-unit probabilistic safety assessment (PSA) models for regulatory verification [4], we introduce the preliminary results of PSA model incorporating portable equipment for a single unit of Westinghouse 600 MWe type.

2. Development of a PSA model

When we reflect the portable equipment to the PSA model, it is necessary to consider available equipment and scenarios, and purpose of the use. In this analysis, we consider a 1MW portable generator and a low pressure portable pump, which can supply electric power and water for the mitigation action of the plant. The 1MW generator may be considered when an alternative alternating current diesel generator (AAC DG) is unavailable and offsite power cannot be recovered, which is called the extended loss of AC power (ELAP). The power from the 1MW generator supplies battery charger for the control power of the turbine-driven auxiliary feedwater pump and power of the essential instrument, so that secondary heat removal can be maintained. On the other hand, the low pressure portable pump can supply feedwater to a steam generator. The pump can replace the turbine-driven auxiliary feedwater pump when performing secondary heat removal after connecting the 1MW generator. It is possible to determine that the scenarios with the two facilities may not progress to the core damage though it is difficult to recover AAC DG and offsite power. Figure 1 shows the simplified event tree reflecting the portable equipment, where blue lines are added as the equipment is considered. In addition, the fault trees related to the portable equipment are also shown in Figure 2 and Figure 3.

There are several considerations in the modeling of PSA for the portable equipment. It is important to note which scenarios are available for the equipment. For example, when the emergency diesel generator (EDG) or AAC DG is unavailable due to the failure of the circuit breaker connected to the 6.9kV bus, the 1MW generator is also unavailable. In this case, it is not possible to credit the 1MW generator.

In addition, the available load for the portable equipment should be identified. During the secondary heat removal, the atmospheric dump valve (ADV) needs the instrument air (IA), which requires the support system such as component cooling water and essential service water systems. Since the 1MW generator cannot supply the power to the support systems, it is necessary to consider the situation in which the operator operates the ADV in local.

In the analysis, the failure probability of the equipment is assumed to verify the effectiveness of the portable equipment in terms of the modeling.

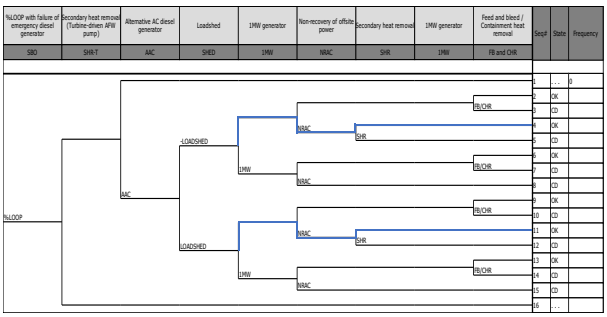

Fig. 1. Simplified event tree for considering portable equipment

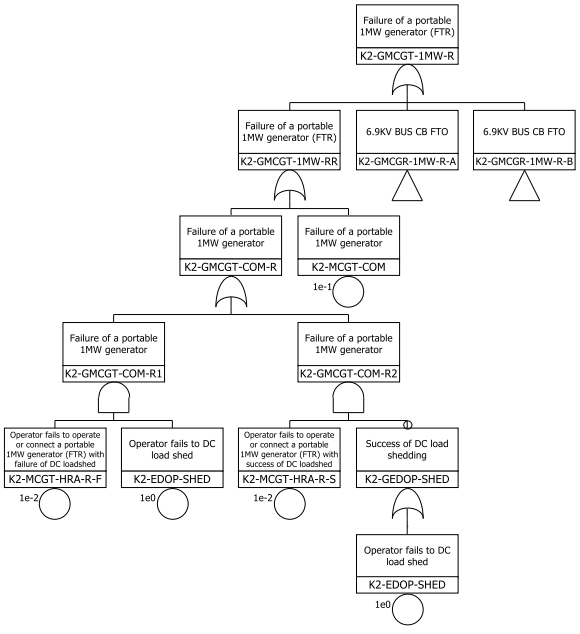

Fig. 2. Fault tree for the 1MW portable generator

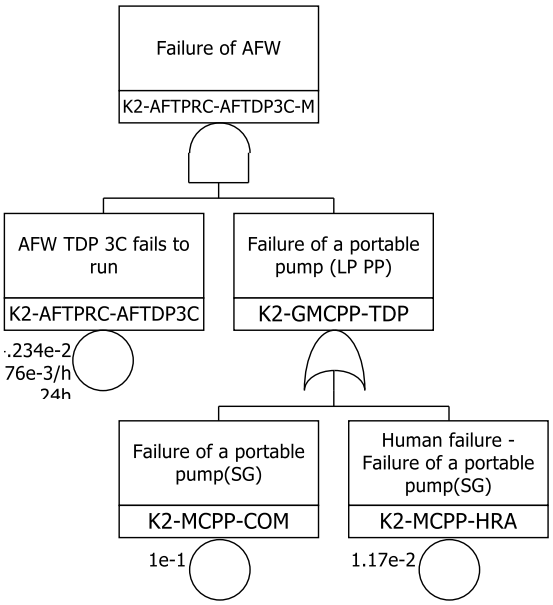

Fig. 3. Fault tree for the low pressure portable pump

3. Preliminary results

The preliminary results of PSA models incorporating portable equipment are shown in Table I. When the 1MW portable generator and low pressure portable pump are reflected to the PSA model, the core damage frequency (CDF) for internal events can decrease by 2%, and CDF for seismic events can decrease by 0.9%. In case of the internal events, the CDF for station blackout due to running failure of emergency diesel generators (SBO-R) is reduced by 18%, but that for starting failure of emergency diesel generators (SBO-S) is reduced by 7%. The difference in the CDF reduction between them is due to the failure of the circuit breaker connected to the 6.9kV bus, which restricts the use of emergency diesel generators. The scenario progresses to SBO-S and it is found that 1MW generator also cannot be connected. For this reason, the effect of the 1MW generator is smaller in the case of SBO-S.
In the seismic events, it is found that the portable equipment has little effect as the ground motion level increases. This is because the human failure for connecting the portable equipment has high failure probability when the ground motion level is high.

Table I: Preliminary result for the PSA models incorporating portable equipment (CDF reduction in percent)

Internal event	
Total	-2 %
LOOP Total	-10 %
LOOP	0 %
SBO-R	-18 %
SBO-S	-7 %

Seismic event			
Total	-0.9 %		
S015	-12 %	S065	0 %
S025	-3 %	S075	0 %
S035	0 %	S085	0 %
S045	0 %	S095	0 %
S055	0 %	S100	0 %

4. Conclusions

This paper provides the preliminary results from the development of single unit PSA models incorporating portable equipment, which contribute to the multi-unit PSA model. It was identified that the CDF can be reduced by reflecting the portable equipment to the PSA models. The risk assessment with portable equipment can contribute to improve the plant safety by reviewing the applicable scenarios and identifying the effects of them.

REFERENCES

[1] EPRI, “Incorporating Flexible Mitigation Strategies into PRA Models (Phase 1: Gap Analysis and Early Lessons Learned)”, Electric Power Research Institute, Palo Alto, California, 2014.
[2] J. Kim, S. Y. Park, K. I. Ahn, J. E. Yang, IROCS: Integrated Accident Management Framework for Coping with Beyond-Design-Basis External Events, Nuclear Engineering and Design, Vol.298, p.1-13, 2016.
[3] KINS, “Report on Stress test for Haul Nuclear Power Plant Units 1, 2 (draft)”, Korea Institute of Nuclear Safety, Korea, 2019. (in Korean)
[4] J. S. Kim, M. C. Kim, K. Son, G. Heo, G. Park, J. Kim, M. Hwang, M. Jae, Modeling portable equipment in probabilistic safety assessment of nuclear power plants, proceeding of Meeting on Probabilistic Safety Assessment and Analysis(PSA2021), Columbus, November 7-12, 2021.